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ON LABORATORY ARTS.

On Laboratory Arts. By Richard Threlfall, M.A., Professor of Physics in the University of Sydney. Pp. xii + 338. (London: Macmillan and Co., Ltd. New York: The Macmillan Company, 1898.)

THERE are certain passages in the preface of Prof. Threlfall's valuable contribution which it may be useful to quote before dealing with the book itself.

> "It often happens that young physicists are to be found whose mathematical attainments are adequate, whose observational powers are perfectly trained, and whose general capacity is unquestioned, but who are quite unable to design or construct the simplest apparatus with due regard to the facility with which it ought to be constructed. That ultimate knowledge of materials and of processes which by long experience becomes intuitive in the mind of a great inventor of course cannot be acquired from books or from any set course of instruction. There are, however, many steps between absolute ignorance and consummate knowledge of the mechanical arts, and it is the object of the following pages to assist the young physicist in making his first steps towards acquiring a working knowledge of 'laboratory art.' . . . Before all things the means indicated must be definite and reliable. It is for this reason that the writer has practically confined himself to matters lying within his own immediate experience, and has never recommended any process (with one or two minor exceptions, which he has noted) which he himself has not actually and personally carried through to a successful issue. . . . With regard to the question as to what matters might be included and what omitted, the general rule has been to include information which the author has obtained with difficulty, and to leave on one side that which he has more easily attained. . . . Though no doubt a great deal can be done with inferior appliances where great economy of money and none of time is an object, the writer has long felt very strongly that English physical laboratory practice has gone too far in the direction of starving the workshop, and he does not wish, even indirectly, to give any countenance to such a mistaken policy."

The writer of this notice feels so strongly the importance of the subject of the first and last of these extracts that it is only with an effort that he can forego the opportunity which they offer of airing views, and confine himself to the more prosaic duty of review.

The second extract is one which shows that the first essential in a work of this kind is complied with. A mere collection of recipes for making and doing all sorts of things which have been collected from anywhere and everywhere, while not absolutely useless, is necessarily untrustworthy. Without the personal certificate of a man who is both a physicist and a mechanician, no description of a process for making or doing anything will necessarily be the most appropriate or even serviceable at all. With such a certificate, however, any one with but little experience of any particular laboratory art may set to work upon it with reasonable confidence.

The first chapter, of ninety pages, is upon the manipulation of glass and on glass-blowing for laboratory purposes. Of all laboratory arts probably glass-blowing and working, not including the work of the optician, looks more easy when practised by an adept, and seems more utterly and hopelessly impossible when tried for the first time, than any other. It is one which every experimentalist must acquire in some degree, and which as a fact, with a little practice and suitable help, is one of the easiest in which to make progress. Shenstone's well-known little book has been found invaluable by many, the little work of Bolas has recently been reviewed in these columns, and now we have new advice on the same subject, differing in some points, as is to be expected, but the result of personal experience. The subject is one in which any opportunity of watching a glass-blower of skill is worth more than any written instruction, but it is one in which occasional and hurried opportunities of watching a process can be supplemented most usefully by description. Practice, however, is essential, whatever guide to procedure may be attainable.

The writer's experience of the average student is that it is not sufficient to tell him even several times that he must not begin glass-blowing operations upon dusty tubes. The very elaborate description of a really proper way of cleaning a glass tube so as to fit it for the best class of work may, perhaps, induce this individual to take the trouble at least to wash out his tubes.

Prof. Threlfall does not approve of the type of blowpipe usually furnished by the instrument maker, nor apparently does any writer on the subject. He describes a simple form of oxygen blowpipe that is suitable for working lead-glass or unusually infusible glass. For larger work with lead-glass he prefers a system of four blowpipes, the flames of which meet upon the work. The superiority of lead-glass where the nature of the experiment will admit of it is duly insisted on. It is a pity that owing to the miserable blowpipes to be found in laboratories, the beginner never gets a chance of realising how excellent lead-glass really is.

The instructions given for cracking or cutting the larger sizes of glass tubes do not quite accord with the writer's experience. The well-known point of melted glass and the flame-pencil with a very small flame are described as being suitable for leading a crack round a tube. The writer has found with tubes that are not too large, a thick copper wire mounted in a handle and bent at the end into such a form as to make a good long contact with the glass, enables one with a little practice to lead a smooth crack round the tube along any predetermined line with an accuracy and quickness not approached by any other process. It is often possible with a single heating of the wire to "cut" a tube an inch or more in diameter either square across or at an angle as great as 30°, and so nearly in a plane that five minutes' grinding on emery cloth will remove the whole of the old surface.

On p. 49 there is a figure showing an ordinary glazier's diamond mounted on a frame, so as to bear upon the exterior of a rotating tube. No doubt as this is described a tube may be cut that way, and in that case, perhaps, no exception should be taken. But since glass tubes cool from the exterior, the inner surface is ultimately in a state of stretch, while the exterior surface is in a state of compression. As a consequence, glass tubes and vessels in general are far more sensitive to even microscopic scratches inside than out. For this reason, it is preferable to mount the diamond at the side of the end of a stick or metal rod provided with a sliding stock like a marking gauge. With such an instrument, tubes may be cut with facility and accuracy. In the same way it is not easy to cut a circular hole in an ordinary glass shade; but if a glazier's diamond is used on a compass within the shade, the piece will drop out at once.

There are useful instructions on boring holes in glass. Of course, the nature of the tool and of the process depends upon the size of hole and thickness of glass. It will be news to most people, however, to read, after the process of drilling with a file is described:

> "It is not, however, necessary to use a file at all, for the twist drills made by the Morse Drill Company are quite hard enough in their natural state to bore glass. The circumferential speed of the drill should not much exceed ten feet per minute. In this way the author has bored holes through glass an inch thick without any trouble, except that of keeping the lubricant sufficiently supplied."

The writer has always believed that a pyramidal end to a drill—that is, a drill of the old-fashioned flat pattern, but with the two faces meeting at the point, not joined by a cross-edge—was the best form for drilling glass, *i.e.* when a diamond drill is not available. Such a drill, made dead hard and well lubricated, certainly drills holes in thick glass with remarkable facility. The success of the Morse twist drill, where such cross-edge is always present, would seem to indicate that there is nothing essential in the pyramid theory. The application of the methods of the mechanical engineer to the work of glass is carried a step further on p. 74, where the reader is told to give up grinding glass to form in many cases where this is the usual practice, but instead to chuck it in the lathe and turn it with a steel tool ground to an edge of 80° and well lubricated. After this, any one who has not worked glass in this way would almost expect to read—the best way to start the Morse drill in glass boring is to use a dead hard and sharp centre punch, and give it a smart blow with a light hammer.

An appendix to the first chapter should be found useful, since the interest in experimenting with Röntgen tubes shows no sign of decaying. Complete and detailed instructions are given for making all the parts of these tubes, for putting them together, for making a suitable pump, and for completing by exhaustion and sealing.

The second chapter is upon glass grinding and optician's work. This is one which the great majority of experimentalists will look upon as outside their practical requirements. There is no doubt that the art of optical grinding, as distinct from mere lapidary performances, is one of the most fascinating for the very few who have laid themselves out to practise it. It, however, is one which cannot be embarked upon in five minutes. A good deal of material and apparatus has to be collected before a start can be made, and at the best the processes seem slow and tedious; they are, moreover, of a kind that cannot be hurried. On the other hand, where the practical physicist finds himself in some outlandish place, it may very well be worth his while to acquire the art of grinding and polishing plane and curved surfaces, and of attaining the skill, if he has the patience, of figuring these with the precision that optical work demands. For those within reach of the real or working optician—quite a distinct type from the shoptician—it is barely worth spending the time for the sake of the work to be done, though it may be for the sake of the pleasure that succeeding in a difficult art will bring to the worker. But this is luxury.

On the other hand, occasions arise in experimental work where it is important to be able to do on the spot and at once some operation of a kind which, taken by itself, the experimentalist would prefer to put in the hand of the instrument maker, but which it may be imperative to perform on the spot, even though the technical success may be inferior to that of a second-rate professional.

The whole series of operations required in making an achromatic object-glass of small size are described, not because any one wanting such a glass would be well advised to make one, but because such a description includes all the ordinary routine of optical work, and a beginner would find it a good training. After this the construction of small lenses and of galvanometer mirrors is described. The author tried making these mirrors of fused quartz and of crystalline quartz, as well as of glass, and has concluded that for the most perfect thin mirrors slices of the crystal are better than anything. In this conclusion the writer of this notice agrees.

The construction of large mirrors and object-glasses for telescopes is dealt with; but in the writer's opinion this, while good enough, is somewhat out of place, for it is not possible to devote enough space to the very wonderful art of testing the surface at the centre of curvature. The formula for the longitudinal aberration of the parabola at this point is not given, nor is the reader warned that the formula of Draper, which is so constantly quoted for this, only gives half the correction.

Sections 68 and 69 should be valuable to many. They are both quotations from Brashear, whose optical masterpieces are known of, if they have not been actually seen by every experimentalist in the world. The first is on the cleaning of dirty object-glasses, and the second on the working of plane surfaces on rock salt.

Some attention is given to the peculiar difficulties of producing optically plane surfaces of any size. Lord Rayleigh's beautiful method of testing the figure by interference with a free surface of water just above it is referred to rather than described. While interference methods of testing are shortly described—and they have the undoubted value that they indicate the magnitude and position of any errors—it is, perhaps, unfortunate that the very handy method of testing the goodness of a plane surface by the use of a telescope and artificial star is not properly described.

The chapter on optical work is really full of valuable information. The fact that some criticism has been offered is perhaps owing to the fact that the subject is one upon which no two people would have quite the same views. The writer must, however, here express his disappointment at not finding any indication of the value of carborundum for these processes. He has never lost an opportunity of trying to collect real experience on this material, practically without success. His own very limited experience is all in favour of the virtues which the makers so forcibly set out. It seems impossible in this country to learn anything about it directly.

The third chapter is on all sorts of things that the manipulator in materials ought to know. The first of these is on Margot's method of coating glass with aluminium and of soldering aluminium, or even glass, by means of its aluminium coat! Prof. Threlfall vouches for the practical ease and success of these processes. He gives full details of the very simple process.

The second is on Boettger's process of depositing bright gold upon glass, just as silver is deposited. This also the author has proved to be satisfactory. The question arises whether it might not be worth while, where colour is not important, to use gold in the place of silver in reflecting telescopes for the sake of the permanence that should in this way be attainable.

The third is on slitting with a disc and diamond dust and making rock sections generally. This, however, does not require particular notice except, perhaps, the curious statement that the author was surprised how difficult it was to learn anything about this art. Vol. iii. of Holtzapffel surely cannot have been in his mind when he wrote this.

A large amount of space is given to the fullest details of the different methods of making and mounting quartz fibres and of their properties. No one with this before him need have any doubt about embarking upon this laboratory art. The writer of this notice had produced the first of some articles on the subject in the *Electrician*, but on seeing Prof. Threlfall's book, felt that the ground was so well and accurately covered that it would be a mistake to go over it again. The curious property of the quartz fibre discovered by Prof. Threlfall, of becoming at ordinary temperatures very slightly *more* rigid as the temperature rises, is referred to; and the suggestion which the writer of this notice also put forward tentatively years ago is made, that chronometer balance-springs made of fused quartz might have some advantage. This curious rise in rigidity with temperature is also noticed by Mr. S. J. Barnett in a valuable paper in the *Physical Review* for February last. Another point referred to by both these writers is the extraordinarily small coefficient of expansion of melted quartz. Benoit gives the extreme coefficients for crystalline quartz as $\cdot 0^5 72$ and $\cdot 0^4 133$. Barnett found for three quartz fibres $\cdot 0^6 3$, and for a rod of fused quartz $\cdot 0^6 2$. There is one part of the description of the manipulation with quartz fibres where the writer would add to Prof. Threlfall's description. On p. 220 the method of handling the fibre, cutting it off, and mounting it so as to be of the right length is described. Instead of a board to work on, however black it may be, a piece of looking-glass lying flat on the table is infinitely superior. This was suggested years ago by some kind friend, but who it was the writer is ungrateful enough not to remember.

The writer prefers when blowing quartz fibres of extreme tenuity for suspension purposes, not to blow a maze on to some screen, but, using a finer flame, to blow out a single fibre which may often be found joining the two rods, and either thick enough to show colour or generally far too fine to do so, corresponding in fact to the black of the soap-bubble.

Soldering, brazing, silver soldering, all essential everyday arts, are next described well and fully; but whether these descriptions will make these actually easy arts ever seem so to beginners is a question. Perhaps enough is not made of the sweating process carried out without any bit, or any preliminary cleaning or preparation of any kind. On the other hand, under brazing and silver soldering, the great use of a bit made of clean iron wire in showing the melted metal where to go when it does not flash at once, might be added in a future edition.

Insulators and conductors used in the construction of apparatus are next considered. Prof. Threlfall is probably the only person who has turned to useful account the writer's discovery of the superlative insulating properties of rods of melted quartz, even in an atmosphere saturated with water. Their application to a number of electrical appliances is described and figured.

Glass, ebonite, mica, micanite, celluloid, paper, paraffin, wood, slate, and marble are all discussed from the point of view of a constructional material with insulating properties. The electrical and mechanical properties of a large number of alloys, such as platinoid, manganin, &c., close this long and most valuable chapter.

The last chapter is upon electro-plating, chiefly gold, silver, copper and nickel, and upon allied arts. The writer has often heard that the best nickel plating is really cobalt. He hoped to, but did not, find any enlightenment upon this point.

An appendix upon platinising glass concludes the book.

This notice, already too prolonged, and yet insufficient, is enough to show that the experimentalist has now a most useful guide in a large number of processes. It is not possible to describe every process. The personal certificate is what gives value to those that are chosen. It is to be hoped that with Prof. Threlfall's valuable guide, instead of despising them, some of our growing physicists may be encouraged to make themselves familiar with some, at any rate, of those arts which Newton and Faraday cultivated with such astonishing skill and success.

C. V. BOYS.

A NEW TEXT-BOOK OF ZOOLOGY.

A Student's Text-Book of Zoology. By Adam Sedgwick, M.A., F.R.S. Vol. i. Pp. 600. (London: Swan Sonnenschein and Co., Ltd., 1898.)

MR. SEDGWICK has produced the first part of what must prove to be a very useful treatise for University students, if the remaining portions of the work are as well carried out as is the present.

In this volume Mr. Sedgwick gives an account of the Protozoa, Porifera, Cœlentera, Platyhelminthes, Nemertea, Nemathelminthes, Rotifera, Mollusca, Annelida, Sipunculoidea, Priapuloidea, Phoronidea, Polyzoa, Brachiopoda, and Chætognatha. The method adopted is strictly systematic: the larger groups are described and characterised in turn, the enumeration extending as far as families, which are also briefly characterised, important illustrative genera being cited. The work is, in fact, written on the lines of the translation of the "Zoology" of Prof. Claus, which Mr. Sedgwick gave us some years ago; but instead of merely producing a new edition of that work, he has written a new book introducing his own views and his own conception as to what are important facts and useful schemes of classification.

A distinctive feature of the work is the number of excellent woodcuts which Mr. Sedgwick has culled from